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MATHEMATICS.—*Strains due to temperature gradients, with special reference to optical glass.* ERSKINE D. WILLIAMSON, Geophysical Laboratory, Carnegie Institution of Washington.

In spite of the fact that the foundations of the mathematical theory of this subject were laid as long ago as 1879,[1] observers have overlooked the simplicity of many of the results and their bearing on practical problems. Some time ago we had occasion to evaluate the stresses that would occur in blocks of glass of various shapes under varying heat treatments and in the following pages we give the results obtained and some remarks on their interpretation.

To get a concrete idea of the nature of the problems, consider a sphere of glass originally homogeneous which is being heated at a uniform rate. Under this heating condition there is set up a determinate temperature gradient such that the outside layers are hotter than those inside. If the sphere were to consist of a number of detached spherical shells, these shells would separate, but if the sphere be solid, internal stresses are set up to counteract the separation effect. For mathematical purposes we may evidently consider these two actions as taking place separately, *i.e.*, we may consider each element of the sphere as undergoing an expansion due to the temperature effect and then being brought back to its equilibrium position by internal stresses.

[1] HOPKINSON, J. Messenger of Math. 8: 168. 1879.

A qualitative idea of the stresses can be immediately obtained. Suppose the black parts in figure 1 represent concentric shells which have become separated by the establishing of temperature differences from shell to shell. To bring these together again will require tensions radially in each of the white sections. The radial tension must increase from the center to the outside as each tension holds in the tension outside it. The effect will

Fig. 1. Concentric Shells.

be radial stretching in all cases, but combined with the stretching in each shell there will be a total displacement inwards or outwards for the outer and inner shells, respectively, and this will result in a change of circumference which will be a decrease for the outer shells and an increase for the inner. The superposition of these effects gives the total strain.

MATHEMATICAL DISCUSSION OF PARTICULAR CASES

I. *Spherical shell with a temperature distribution which is symmetrical about the center.*—Let the infinitesimal shell whose radius is r become finally of radius $r + \rho$ so that $\frac{\rho}{r}$ = the tangential (or circumferential) strain and $\frac{d\rho}{dr}$ = the radial strain. Let P_r represent the radial stress at that point and P_t the tan-

gential. A tension is considered as a positive and a thrust as a negative stress. Then

$$\frac{d\rho}{dr} = e\,P_r - f\,P_t - fP_t + \alpha\theta \qquad (1)$$

$$\text{and } \frac{\rho}{r} = -f\,P_r + e\,P_t - f\,P_t + \alpha\theta \qquad (2)$$

where θ is the change in temperature from the initial condition of no stress, α is the coefficient of linear expansion and e and f are elastic constants for the substance.[2]

The condition of equilibrium shows that

$$P_t = P_r + \frac{r}{2}\cdot\frac{d\,P_r}{dr} \qquad (3)$$

Elimination of ρ and P_t yields

$$r\frac{d^2P_r}{dr^2} + 4\frac{dP_r}{dr} = -\frac{2\,\alpha}{(e-f)}\cdot\frac{d\theta}{dr}$$

and hence

$$r^3P_r = -\frac{2\,\alpha}{(e-f)}\int r^2\theta\,dr + C_1\frac{r^3}{3} + C_2 \qquad (4)$$

where C_1 and C_2 are constants to be evaluated by the boundary conditions. P_t is then evaluated from equation (3).

II. *Solid sphere with a temperature distribution which is symmetrical about the center.*—This differs from the previous case only in the evaluation of the integration constants. C_2 must vanish as $\frac{d\theta}{dr}$ and $\frac{dP}{dr}$ must be zero at $r = o$.

Hence

$$r^3P_r = -\frac{2\,\alpha}{(e-f)}\int r^2\theta\,dr + C_1\frac{r^3}{3} \qquad (5)$$

III. *Cylindrical shell or tube with temperature distribution symmetrical about the axis.*—In this case we made the assumption that planes perpendicular to the axis remained plane. Except at the ends this is justified and in fact it was found to be com-

[2] Young's modulus and Poisson's ratio, for the substance in question are $\frac{1}{e}$ and $\frac{f}{e}$, respectively.

pletely justified so far as experiment[3] was possible.

If the stresses be P_1, P_2, and P_3, parallel to the axis, radially, and tangentially in the plane at right angles to the axis; respectively, and X be the displacement parallel to the axis of the element originally defined by the coordinates (x, r), the elastic equations are:

$$\frac{dX}{dx} = eP_1 - fP_2 - fP_3 + \alpha\theta = \text{constant}$$

$$\frac{d\rho}{dr} = -fP_1 + eP_2 - fP_3 + \alpha\theta$$

$$\frac{\rho}{r} = -fP_1 - fP_2 + eP_3 + \alpha\theta$$

$$P_3 = P_2 + r\frac{dP_2}{dr}$$

$$\int_o^a P_1 r dr = o$$

The last two equations are necessary for mechanical equilibrium and the substitution of a constant for $\frac{dX}{dx}$ is the form taken by the assumption mentioned above.

Elimination yields

$$(e-f)\frac{dP_1}{dr} + \alpha\frac{d\theta}{dr} = o$$

or
$$(e-f)\,P_1 + \alpha\theta = C_1 \qquad (6)$$

also
$$3\frac{dP_2}{dr} + r\frac{d^2P_2}{dr^2} = -\frac{\alpha}{(e-f)}\cdot\frac{d\theta}{dr}$$

yielding
$$r^2P_2 = -\frac{\alpha}{e-f}\int r\theta dr + \frac{C_2r^2}{2} + C_3 \qquad (7)$$

The value of P_3 is then obtained from

$$P_3 = P_2 + r\frac{dP_2}{dr}$$

[3] The experiments bearing on this will be published in the series of papers on optical glass now in the course of publication by this Laboratory.

IV. *Solid cylinder with temperature distribution symmetrical about the axis.*—The only change necessary is that C_2 in equation (7) vanishes owing to $\frac{dP_2}{dr}$ and $\frac{d\theta}{dr}$ being zero at $r = o$.

V. *Slab with temperature gradient through the smallest dimensions, symmetrical about the center.*—The same assumption was made as regards planeness as in the axial displacement for the cylinder and the forces along the line of the temperature gradient are neglected. (See previous footnote as regards experimental evidence.)

The equations then are:

$$eP - fP + \alpha\theta = \text{constant} = C_1$$

and

$$\int_o^a P\,dx = o$$

The integral gives us a method of evaluating the required constant,

$$\int_o^a \frac{C_1 - \alpha\theta}{e - f}\,dx = o$$

or

$$\int_o^a C_1\,dx = \alpha\int_o^a \theta\,dx$$

APPLICATION OF THESE EQUATIONS TO SPECIFIC CASES[4]

I. *Spherical shell.*

(I*a*). *Shell heated linearly on the surface.*

(I*b*). *Approximate formulae for the same case when the internal diameter is very small.*

(I*a*).[5] In this case

$$\frac{d\theta}{dr} = \frac{hr}{3\kappa} - \frac{ha_1^3}{3\kappa r^2}.$$

Equation (4) therefore reduces to

[4] The temperature gradients $\left(\frac{d\theta}{dr}\right)$ in all cases are taken from a forthcoming paper on temperature distribution in solids, by E. D. WILLIAMSON and L. H. ADAMS.

[5] h = rate of heating; κ = diffusivity constant.

$$P_r = -\frac{2\alpha}{(e-f)}\left(\frac{hr^2}{30\kappa} + \frac{ha_1^3}{6\kappa r}\right) + \frac{C_1}{3} + \frac{C_2}{r^3}$$

But $P_r = o$ at $r = a$ and $r = a_1$ so that C_1 and C_2 may be evaluated, yielding

$$P_r = \frac{\alpha h}{15\kappa(e-f)}\left[-r^2 - \frac{5a_1^3}{r} + \frac{a^5 + 5a^3a_1^2 - 6a_1^5}{a^3 - a_1^3} - \frac{a^5a_1^3 - 2a^3a_1^5 + a^2a_1^6}{(a^3 - a_1^3)r^3}\right]$$

$$P_t = \frac{\alpha h}{15\kappa(e-f)}\left[-2r^2 - \frac{5a_1^3}{2r} + \frac{a^5 + 5a^3a_1^2 - 6a_1^5}{a^3 - a_1^3} + \frac{a^5a_1^3 - 2a^3a_1^5 + a^2a_1^6}{2(a^3 - a_1^3)r^3}\right]$$

(I*b*). The values are obtained by assuming a_1 small enough to be negligible compared with a.

$$P_r = \frac{\alpha h}{15\kappa(e-f)}\left(-r^2 + a^2 - \frac{a^2a_1^3}{r^3}\right)$$

$$P_t = \frac{\alpha h}{15\kappa(e-f)}\left(-2r^2 + a^2 + \frac{a^2a_1^3}{r^3}\right)$$

II. *Solid sphere.* Linear heating, on outside surface.

The treatment is exactly as in the previous case and the resulting equations are:

$$\frac{d\theta}{dr} = \frac{hr}{3\kappa}$$

$$P_r = \frac{\alpha h}{15\kappa\,(e-f)}\left[-r^2 + a^2\right]$$

$$P_t = \frac{\alpha h}{15\kappa\,(e-f)}\left[-2r^2 + a^2\right]$$

Except at the center these agree with case (I*b*). At the center in the case of a sphere we have a tension in all directions of $\frac{\alpha\, ha^2}{15\kappa(e-f)}$ but if there be a very small cavity the stresses must be got from (I*b*), and it is found that the radial stress vanishes while the tangential tension is double the value for the solid sphere. It follows that small cavities, due for example to bubbles, make glass much more liable to breakage during heat treatment.

In the case of the solid sphere it is also interesting to find the elastic strains. These are got by substituting the values of P_r and P_t in equations (1) and (2). This yields

$$\text{Tangential extension}^6 = \frac{\alpha h}{15\kappa\left(\frac{1}{6n}+\frac{2}{9k}\right)}\left[\frac{a^2}{3k}-r^2\left(\frac{1}{6n}+\frac{5}{9k}\right)\right]$$

$$\text{Radial extension}^6 = \frac{\alpha h}{15\kappa\left(\frac{1}{6n}+\frac{2}{9k}\right)}\left[\frac{a^2}{3k}+r^2\left(\frac{1}{3n}-\frac{5}{9k}\right)\right]$$

The nature of these strains was predicted at the beginning of this paper, and it can be seen that in general the suggestions were correct. The radial extension is practically constant for it is approximately true for most solids that $4f = e$, which gives

$$\frac{1}{3n}-\frac{5}{9k}=0.$$

On the other hand, the tangential extension is equal to the radial at the center, but diminishes, passes through zero and becomes a compression for larger values of r.

The form of these expressions shows that the stress at any point may be analyzed into a hydrostatic tension proportional to $a^2-\frac{5r^2}{3}$ combined with a shearing stress which causes radial elongation and tangential contraction proportional to $1+\frac{r^2}{3n}$ and $1-\frac{r^2}{6n}$, respectively.

III. *Cylindrical tube.*

Since the analysis is exactly similar, only the bare results are written for the two cases considered, namely:

(III*a*). Linear heating, on outside only.

$$\frac{d\theta}{dr}=\frac{hr}{2\kappa}-\frac{ha_1^2}{2\kappa r}$$

[6] The values of the constants e and f are here expressed in terms of k (the compressibility modulus) and n (the rigidity modulus). $e=\frac{1}{3n}+\frac{1}{9k}$, $f=\frac{1}{6n}-\frac{1}{9k}$.

$$P_1 = \frac{\alpha h\left(\frac{a^2}{2} - r^2\right)}{4\kappa(e-f)} + \frac{\alpha h a_1^2}{4\kappa(e-f)}\left(\ln\frac{r^2}{a^2} - 1\right)$$

$$P_2 = -\frac{\alpha h r^2}{16\kappa(e-f)} + \frac{\alpha h a_1^2}{4\kappa(e-f)}\left(\ln r - \frac{1}{2}\right) + \frac{C_1}{2} + \frac{C_2}{r^2}$$

where C_1 and C_2 are evaluated by equating the right hand expression to zero for $r = a$ and $r = a_1$.

$$P_3 = -\frac{3\alpha h r^2}{16\kappa(e-f)} + \frac{\alpha h a_1^2}{4\kappa(e-f)}\left(\ln r + \frac{1}{2}\right) + \frac{C_1}{2} - \frac{C_2}{r^2}$$

where C_1 and C_2 have the values found for the preceding equation.

(III*b*). For a small-bored tube. Linear heating, on outside only.

$$P_1 = \frac{\alpha h(a^2 - 2r^2)}{8\kappa(e-f)}$$

$$P_2 = \frac{\alpha h\left(a^2 - r^2 - \frac{a^2 a_1^2}{r^2}\right)}{16\kappa(e-f)}$$

$$P_3 = \frac{\alpha h\left(a^2 - 3r^2 + \frac{a^2 a_1^2}{r^2}\right)}{16\kappa(e-f)}$$

(IV). *Solid cylinder.* Linear heating, on outside only.

$$\frac{d\theta}{dr} = \frac{hr}{2\kappa}$$

$$P_1 = \frac{\alpha h(a^2 - 2r^2)}{8\kappa(e-f)}$$

$$P_2 = \frac{\alpha h(a^2 - r^2)}{16\kappa(e-f)}$$

$$P_3 = \frac{\alpha h(a^2 - 3r^2)}{16\kappa(e-f)}.$$

(V). *Slab.* Linear heating, on outside only.

$$\frac{d\theta}{dr} = \frac{hr}{\kappa}$$

$$P = \frac{\alpha h}{2\kappa(e-f)}\left(\frac{a^2}{3} - r^2\right)$$

In all the cases except that of the sphere (for which the calculations are exact) it must be emphasized that the calculated stresses are the maximum values on the assumption that no relief takes place by bending. It will be shown in a later paper that the stresses actually occurring approximate very closely to the values thus calculated.

SUMMARY

General equations are derived for the elastic stresses produced by temperature differences in spheres, cylinders, and slabs when the temperature distribution is symmetrical about the center, axis, or central plane respectively.

More specific equations are given for the case of the temperature distribution due to uniform surface heating, which is the most important case in practice.

ASTRONOMY.—*Modern theories of the spiral nebulae.*[1] HEBER D. CURTIS, Lick Observatory. (Communicated by W. J. Humphreys.)

In one sense, that theory of the spiral nebulae to which many lines of recently obtained evidence are pointing, can not be said to be a modern theory. There are few modern concepts which have not been explicitly or implicitly put forward as hypotheses or suggestions long before they were actually substantiated by evidence.

The history of scientific discovery affords many instances where men with some strange gift of intuition have looked ahead from meager data, and have glimpsed or guessed truths which have been fully verified only after the lapse of decades or centuries. Herschel was such a fortunate genius. From the proper motions of a very few stars he determined the direction of the sun's movement nearly as accurately, due to a very happy selection of stars for the purpose, as far more elaborate modern investigations. He noticed that the star clusters which appeared

[1] Abstract of a lecture given on March 15, 1918, at a joint meeting of the Washington Academy of Sciences and the Philosophical Society of Washington. The lecture was illustrated with numerous lantern slides.

nebulous in texture in smaller telescopes and with lower powers, were resolved into stars with larger instruments and higher powers. From this he argued that all the nebulae could be resolved into stars by the application of sufficient magnifying power, and that the nebulae were, in effect, separate universes, a theory which had been earlier suggested on purely hypothetical or philosophical grounds, by Wright, Lambert, and Kant. From their appearance in the telescope he, again with almost uncanny prescience, excepted a few as definitely gaseous and irresolvable.

This view held sway for many years; then came the results of spectroscopic analysis showing that many nebulae (those which we now classify as diffuse or planetary) are of gaseous constitution and can not be resolved into stars. The spiral nebulae, although showing a different type of spectrum, were in most theories tacitly included with the known gaseous nebulae.

We have now, as far as the spiral nebulae are concerned, come back to the standpoint of Herschel's fortunate, though not fully warranted deduction, and the theory to which much recent evidence is pointing, is that these beautiful objects are separate galaxies, or "island universes," to employ the expressive and appropriate phase coined by Humboldt.

By means of direct observations on the nearer and brighter stars, and by the application of statistical methods to large groups of the fainter or more remote stars, the galaxy of stars which forms our own stellar universe is believed to comprise perhaps a billion suns. Our sun, a relatively inconspicuous unit, is situated near the center of figure of this galaxy. This galaxy is not even approximately spherical in contour, but shaped like a lens or thin watch; the actual dimensions are highly uncertain; Newcomb's estimate that this galactic disk is about 3,000 light-years in thickness, and 30,000 light-years in diameter, is perhaps as reliable as any other.

Of the three classes of nebulae observed, two, the diffuse nebulosities and the planetary nebulae, are typically a galactic phenomenon as regards their apparent distribution in space, and are rarely found at any distance from the plane of our Milky Way. With the exception of certain diffuse nebulosities

whose light is apparently a reflection phenomenon from bright stars involved within the nebulae, both these types are of gaseous constitution, showing a characteristic bright-line spectrum.

Differing radically from the galactic gaseous nebulae in form and distribution, we find a very large number of nebulae predominantly spiral in structure. The following salient points must be taken into account in any adequate theory of the spiral nebulae.

1. In apparent size the spirals range from minute flecks, just distinguishable on the photographic plate, to enormous spirals like *Messier* 33 and the Great Nebula in Andromeda, the latter of which covers an area four times greater than that subtended by the full moon.

2. Prior to the application of photographic methods, fewer than ten thousand nebulae of all classes had been observed visually. One of the first results deduced by Director Keeler from the program of nebular photography which he inaugurated with the Crossley Reflector at Lick Observatory, was the fact that great numbers of small spirals are within reach of modern powerful reflecting telescopes. He estimated their total number as 120,000 early in the course of this program, and before plates of many regions were available. I have recently made a count of the small nebulae on all available regions taken at the Lick Observatory during the past twenty years[2] and from these counts estimate that there are at least 700,000 spiral nebulae accessible with large reflectors.

3. The most anomalous and inexplicable feature of the spiral nebulae is found in their peculiar distribution. They show an apparent abhorrence for our galaxy of stars, being found in greatest numbers around the poles of our galaxy. In my counts I found an approximate density of distribution as follows:

Galactic Latitude $+45°$ to $+90°$	34 per square degree.
Galactic Latitude -45 to $-90°$	28 per square degree.
Galactic Latitude $+30°$ to $+45°$ and $-30°$ to $-45°$	24 per square degree.
Galactic Latitude $-30°$ to $+30°$	7 per square degree.

[2] CURTIS, H. D. *On the number of spiral nebulae*, Proc. Amer. Phil. Soc. **57**: 513. 1918.

No spiral has as yet been found actually within the structure of the Milky Way. We have doubled and trebled our exposures in regions near the galactic plane in the hope of finding fainter spirals in such areas, but thus far without results. The outstanding feature of the space distribution of the spirals is, then, that they are found in greatest profusion where the stars are fewest, and do not occur where the stars are most numerous. This distribution may be illustrated graphically as follows:

THE FACTORS OF SPACE DISTRIBUTION

400,000 ± Spiral Nebulae

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Our own stellar universe
is shaped like a thin lens, and is perhaps
3,000 by 30,000 light-years in extent. In this
space occur nearly all the stars, nearly all the new stars, nearly
all the variable stars, most of the diffuse and
planetary nebulae, etc., but *no spiral*
nebulae.

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300,000 ± Spiral Nebulae.

4. The spectrum of the spirals is practically the same as that given by a star cluster, showing a continuous spectrum broken by absorption lines. A few spirals show bright-line spectra in addition.

5. The space-velocities of the various classes of celestial objects are summarized in the following short table:

TABLE

THE FACTORS OF SPACE-VELOCITY

1. *The Diffuse Nebulae.*
   Velocities low.
2. *The Stars.*
   Velocities vary with spectral type.
   Class B Stars: average speeds 8 miles per second.
   Class A Stars: average speeds 14 miles per second.
   Class F Stars: average speeds 18 miles per second.
   Class G Stars: average speeds 19 miles per second.
   Class K Stars: average speeds 21 miles per second.
   Class M Stars: average speeds 21 miles per second.
3. *The Star Clusters.*
   Velocities unknown.
4. *The Planetary Nebulae.*
   Average speeds 48 miles per second.
5. *The Spiral Nebulae.*
   Average speeds 480 miles per second.

The peculiar variation of the space-velocity of the stars with spectral type may ultimately prove to be a function of relative mass. The radial velocities of but few spirals have been determined to date; future work may change the value given, but it seems certain that it will remain very high.

It will be seen at once that, with regard to this important criterion of space-velocity, the spiral nebulae are very distinctly in a class apart. It seems impossible to place them at any point in a coherent scheme of stellar evolution. We can not bridge the gap involved in postulating bodies of such enormous space velocities either as a point of stellar origin, or as a final evolution product.

On the older theory that the spirals are a part of our own galaxy, it is impossible to harmonize certain features of the data thus far presented. If this theory is true, their grouping near the galactic poles, inasmuch as all evidence points to a flattened or disk form for our galaxy, would indicate that they are relatively close to us. In that event, we should inevitably have detected in this class of objects proper motions of the same order of magnitude as those found for the stars at corresponding distances. Such proper motions are the more to be ex-

pected in view of the fact that the average space velocity of the spirals is about thirty times that of the stars. I have repeated all the earlier plates of the Keeler nebular program, and was able to find no certain evidence of either translation or rotation in these objects in an average time interval of thirteen years.[3] Their form, and the evidence of the spectroscope, indicate, however, that they are in rotation. Knowing that their space-velocities are high, the failure to detect any certain evidence of cross motion is an indication that these objects must be very remote.

Even if the spiral is not a stage in stellar evolution, but a class apart, is it still possible to assume that they are, notwithstanding, an integral part of our own stellar universe, sporadic manifestations of an unknown line of evolutionary development, driven off in some mysterious manner from the regions of greatest star density?

A relationship between two classes of objects may be one of avoidance just as logically as one of contiguity. It has been argued that the absolute avoidance which the spirals manifest for the galaxy of the stars shows incontrovertibly that they must, by reason of this very relationship of avoidance, be an integral feature of our galaxy. This argument has proved irresistible to many, among others to so keen a thinker as Herbert Spencer, who wrote:

> In that zone of celestial space where stars are excessively abundant nebulae are rare; while in the two opposite celestial spaces that are furthest removed from this zone nebulae are abundant . . . . . Can this be mere coincidence? When to the fact that the general mass of the nebulae are antithetical in position to the general mass of the stars, we add the fact that local regions of nebulae are regions where stars are scarce . . . . . does not the proof of a physical connection become overwhelming?

It must be admitted that a distribution, which has placed three-quarters of a million objects around the poles of our galaxy, would be against all probability for a class of objects which would be expected to be arranged at random, unless it can be shown

[3] CURTIS, H. D. *The proper motion of the nebulae.* Publ. Astron. Soc. Pacific 27: 214. 1915.

that this peculiar grouping is only apparent, and due to some phenomenon in our own galaxy. This point will be reverted to later.

It has been shown that the factors of space-velocity and space-distribution separate the spirals very clearly from the stars of our galaxy; from these facts alone, and from the evidence of the spectroscope, the island universe theory is given a certain measure of credibility.

Another line of evidence has been developed within the past two years, which adds further support to the island-universe theory of the spiral nebulae.

NEW STARS

Within historical times some twenty-seven new stars have suddenly flashed out in the heavens. Some have been of interest only to the astronomer; others, like that of last June, have rivaled *Sirius* in brilliancy. All have shown the same general history, suddenly increasing in light ten thousand-fold or more, and then gradually, but still relatively rapidly, sinking into obscurity again. They are a very interesting class, nor has astronomy as yet been able to give any universally accepted explanation of these anomalous objects. Two of these novae had appeared in spiral nebulae, but this fact had not been weighed at its true value. Within the past two years over a dozen novae have been found in spiral nebulae, all of them very faint, ranging from about the fourteenth to the nineteenth magnitudes at maximum. Their life history, so far as we can tell from such faint objects, appears to be identical with that of the brighter novae. Now the brighter novae of the past, that is, those which have not appeared in spirals, have almost invariably been a galactic phenomenon, located in or close to our Milky Way, and they have very evidently been a part of our own stellar system. The cogency of the argument will, I think, be apparent to all, although the strong analogy is by no means a rigid proof. If twenty-seven novae have appeared in our own galaxy within the past three hundred years, and if about half that number are found within a few years in spiral nebulae far

removed from the galactic plane, the presumption that these spirals are themselves galaxies composed of hundreds of millions of stars is a very probable one.

If, moreover, we make the reasonable assumption that the new stars in the spirals and the new stars in our own galaxy average about the same in size, mass, and absolute brightness, we can form a very good estimate of the probable distance of the spiral nebulae, regarded as island universes. Our galactic novae have averaged about the fifth magnitude. The new stars which have appeared in the spiral nebulae have averaged about the fifteenth magnitude, but it would appear probable that we must inevitably miss the fainter novae in such distant galaxies, and it is perhaps reasonable to assume that the average magnitude of the novae in spirals may be about the eighteenth, or thirteen magnitudes fainter than those in our own galaxy. They would thus be about 160,000 times fainter than our galactic novae, and on the assumption that both types of novae average the same in mass, absolute luminosity, etc., the novae in spirals should be four hundred times further away. We do not know the average distance of the new stars which have appeared in our own galaxy, but 100,000 light-years is perhaps a reasonable estimate. This would indicate a distance of the order of 4,000,000 light-years for the spiral nebulae. This is an enormous distance, but, if these objects are galaxies like our own stellar system, such a distance accords well with their apparent dimensions. Our own galaxy, at a distance of 10,000,000 light-years, would be about 10 minutes of arc in diameter, or the size of the larger spiral nebulae.

On such a theory, a spiral structure for our own galaxy would be probable. Its proportions accord well with the degree of flattening observed in the majority of the spirals. We have very little actual evidence as to a spiral structure for our galaxy; the position of our sun relatively close to the center of figure of the galaxy, and our ignorance of the distances of the remoter stars, renders such evidence very difficult to obtain. A careful study of the configurations and star densities in the Milky Way has led Professor Easton, of Amsterdam, to postulate a spiral structure for our galaxy.

DISTRIBUTION OF SPIRALS

There is still left one outstanding and unexplained problem in the island universe theory or any other theory of the spiral nebulae. Neither theory, as outlined, offers any satisfactory explanation of the remarkable distribution of the spirals. On the older theory, if a feature of our galaxy, what has driven them out to the points most remote from the regions of greatest star density? If, on the other hand, the spirals are island universes, it is against all probability that our own universe should have chanced to be situated about half way between two great groups of island universes, and that not a single object of the class happens to be located in the plane of our Milky Way.

There is one very common characteristic of the spirals which may be tentatively advanced as an explanation of the peculiar grouping of the spirals.

A very considerable proportion of the spirals show indubitable evidence of occulating matter, lying in the plane of the greatest extension of the spiral, generally outside the whorls, but occasionally between the whorls as well. This outer ring of occulting matter is most easily seen when the spiral is so oriented in space as to turn its edge toward us. But the phenomenon is also seen in spirals whose planes make a small, but appreciable angle with our line of sight, manifesting itself in such appearances as "lanes" more prominent on one side of the major axis of the elongated elliptical projection, in a greater brightness of the nebular matter on one side of this major axis, in a fan-shaped nuclear portion, or in various combinations of these effects. The phenomenon is a very common one. Illustrations of seventy-eight spirals showing evidences of occulting matter in their peripheral equatorial regions, with a more detailed discussion of the forms observed, are now being published,[4] and additional examples of the phenomenon are constantly being found.

While we have as yet no definite proof of the existence of such a ring of occulting matter lying in our galactic plane and outside of the great mass of the stars of our galaxy, there is a

[4] CURTIS, H. D. *Occulting effects of spiral nebulae.* Univ. Calif. Semi-Cent. Publ. (in press).

great deal of evidence for such occulting matter in smaller areas in our galaxy. Many such dark areas are observed around certain of the diffuse nebulosities, or seen in projection on the background furnished by such nebulosities or the denser portions of the Milky Way; these appearances seem to be actual "dark nebulae."[5] The curious "rifts" in the Milky Way may well be ascribed, at least in part, to such occulting matter.

Though we thereby run the risk of arguing in a circle, the fact that no spirals can be detected in our galactic plane, a natural result of such a ring of occulting matter, would in itself appear to lend some probability to the hypothesis. The peculiar distribution of the spiral nebulae would then be explained as due, not to an actual asymmetrical and improbable distribution in space, but to a cause within our own galaxy, assumed to be a spiral with a peripheral ring of occulting matter similar to that observed in a large proportion of the spirals. The argument that the spirals must be an integral feature of our own galaxy, based on a relationship of avoidance, would then lose its force. The explanation appears to be a possibility, even a strong probability, on the island universe theory, and I known of no other explanation, on any theory, for the observed phenomenon of nebular distribution about our galactic poles.

SUMMARY

The Spiral Nebulae as Island Universes.

1. On this theory, it is unnecessary to attempt to coordinate the tremendous space-velocities of the spirals with the thirty-fold smaller values found for the stars. Very high velocities have been found for the Magellanic Clouds, which may possibly be very irregular spirals, relatively close to our galaxy.

2. There is some evidence for a spiral structure in our own galaxy.

3. The spectrum of the majority of the spirals is practically identical with that given by a star cluster; a spectrum of this general type is such as would be expected from a vast congeries of stars.

[5] BARNARD, E. E. *On the dark markings of the sky*, with a catalogue of 182 such objects. Astrophys. Journ. 49: 1. 1919; CURTIS, H. D. *Dark nebulae*. Publ. Astron. Soc. Pacific 30: 65. 1918.

4. If the spirals are separate universes, similar to our galaxy in extent and in number of component stars, we should observe many new stars in the spirals, closely resembling in their life history the twenty-seven novae which have appeared in our own galaxy. Over a dozen such novae in spirals have been found, and it is probable that a systematic program of repetition of nebular photographs will add greatly to this number. A comparison of the average magnitudes of the novae in spirals with those of our own galaxy indicates a distance of the order of 10,000,000 light-years for the spirals. Our own galaxy at this distance would appear 10′ in diameter, the size of the larger spirals.

5. A considerable proportion of the spirals show a peripheral equatorial ring of occulting matter. So many instances of this have been found that it appears to be a general though not universal characteristic of the spirals; the existence of such an outer ring of occulting matter in our own galaxy, regarded as a spiral, would furnish an adequate explanation of the peculiar distribution of the spirals. There is considerable evidence of such occulting matter in our galaxy.

An English physicist has cleverly said that any really good theory brings with it more problems than it removes. It is thus with the island-universe theory. It is impossible to do more than to mention a few of these problems, with no attempt to divine those which may ultimately be presented to us.

While the data are too meager as yet, several attempts have been made to deduce the velocity of our own galaxy within the super-galaxy. It would not be surprising if the space-velocity of our galaxy, like those of the spirals and the Magellanic Clouds, should prove to be very great, hundreds of miles per second.

Further, what are the laws which govern the forms assumed, and under which these spiral whorls are shaped? Are they stable structures; are the component stars moving inward or outward? A beginning has been made by Jeans and other mathematicians on the dynamical problems involved in the structure of the spirals. The field for research is, like our subject matter, practically infinite.

ABSTRACTS

Authors of scientific papers are requested to see that abstracts, preferably prepared and signed by themselves, are forwarded promptly to the editors. The abstracts should conform in length and general style to those appearing in this issue.

GEOLOGY.—*Two lamprophyre dikes near Santaquin and Mount Nebo, Utah.* G. F. LOUGHLIN. U. S. Geol. Survey Prof. Paper 120–E. Pp. 9. 1918.

There is no local evidence by which these lamprophyre dikes can be correlated with other igneous rocks. It is assumed that they represent a late stage of the Tertiary volcanic period. The dike rocks are dark gray to black, dense, and porphyritic. Biotite is the only conspicuous megascopic mineral, and constitutes about 20 per cent of the rock. The northern dike has a glassy groundmass crowded with phenocrysts of augite, biotite, olivine, and magnetite, and minute crystals of apatite. The southern dike consists of phenocrysts of biotite, augite, apatite, and magnetite in a groundmass of feldspar. The chemical composition of the northern dike is shown by analysis and compared with rocks of similar composition. The rock is classed as a vitrophyric albite minette. It seems probable that the two minettes discussed are genetically related to a monzonitic magma represented by the latite breccias and flows of the region. R. W. STONE.

GEOLOGY.—*New graphic method for determining the depth and thickness of strata and the projection of dip.* HAROLD S. PALMER. U. S. Geol. Survey Prof. Paper 120–G. Pp. 7. with 3 plates and 5 figures. 1918.

This paper presents three charts by means of which rapid solution of the following problems may be made, namely: (1) to find the depth to a stratum, given the dip and distance from the outcrop; (2) to find the thickness of a bed or series of beds, given the dip and the distance across the outcrop; and (3) to find the inclination of the trace of a plane upon a second plane, given the dip of the first plane and the angle between the strike of the two planes.

Simple directions for the use of the charts are followed by a discussion of the principles and accuracy of the method. H. S. P.

ENTOMOLOGY.—*The question of the phylogenetic origin of termite castes.* CAROLINE BURLING THOMPSON and THOMAS ELLIOTT SNYDER. Biol. Bull. **36:** 115–129, 2 plates, 5 text figs. February, 1919.

The recent observation of one of the authors, that the castes of termites are of germinal origin and not produced by environmental conditions, leads to the question of the phylogenetic origin of these variations or castes. Are termite castes to be considered as fluctuating variations or as mutations?

Several lines of approach lead to this problem; the study of fossil insects; the comparative morphology of termites; exact field observations on termite biology; breeding experiments to determine the type of progeny and the results of hybridization. Although none of these aspects have been exhaustively studied, there are some data, summarized in this paper, drawn from the literature of social insects and from the notes of the two authors.

The morphological facts show that a gradation of characters may be traced throughout the members (castes of a species, *e. g.*, *Reticulitermes flavipes*). These castes might be interpreted either as the gradations in a series of fluctuating variations, or as a series of mutations formed by loss.

Field observations and breeding experiments seem to indicate that although the "first form" reproductive individuals produce young of all the castes, the "second" and "third form" individuals breed true to their own fertile castes. In some breeding experiments in artificial nests, from parent reproductive individuals of the "second form" no fertile individuals of any kind were produced.

The authors intend to undertake a series of studies and experiments upon the morphology and the breeding of the termite castes. C. B. T.

PALEONTOLOGY.—*Appendages of trilobites.* CHARLES D. WALCOTT. Smiths. Misc. Coll. **67:** No. 4, Cambrian Geol. and Pal. IV. 115–216, pls. 14–42, text figs. 1–3. December, 1918.

In this recent paper Dr. Charles D. Walcott summarizes his investigations of the appendages of trilobites during the past forty-five years, a research undertaken in pursuance of a promise made to Professor Louis Agassiz in 1873. Since that time, he writes, "I have examined and studied all the trilobites that were available for evidence bearing on their structure and organization."

His first summary of 1881[1] is reviewed and corrected, together with later papers[2] discussing his various discoveries in this subject. The highly organized trilobite, *Neolenus serratus* (Rominger), from the Burgess shale quarry opened by Dr. Walcott, near Field, British Columbia, several years ago, shows most graphically in the ten plates devoted to its illustration the highly specialized development of appendages, which is also figured in plates of the Ordovician trilobites, *Isotelus*, *Triarthrus*, *Calymene*, and *Ceraurus*. In the figure of *Neolenus* the appendages include antennules, caudal rami, endopodites, epipodites, exopodites, exites, and protopodites. The evidence of appendages is supplemented by numerous figured sections of *Ceraurus* and *Calymene*.

After discussing the mode of occurrence, conditions of preservation, manner of life including methods of progression, food, defense, and offense, the author describes species with appendages, which include besides the genera already mentioned, *Kootenia dawsoni* (Walcott), two species of *Ptychoparia* including a new one, *P. permulta*, from the Burgess shale quarry, *Odontopleura trentonensis* (Hall), *Trinucleus concentricus* Eaton, and an unidentified Ordovician crustacean leg. The work of C. E. Beecher with *Triarthrus* is reviewed in some detail, and a different conclusion arrived at in certain features.

In section 2 of the paper the Structure of the Trilobite receives attention, the author again referring to Beecher and other writers including Jaekel, Beyrich, Barrande, and de Volborth. He then discusses in detail the appendages, summarizing them as follows:

Cephalic: (1) Antennules, (2) Antennae, (3) Mandibles, (4) Maxillula, (5) Maxilla; *Thoracic; Abdominal; Caudal rami.*

Further comparisons are with the recent *Anaspides tasmaniae* G. M. Thomson, a Malacostracan from Tasmania, *Koonunga cursor* Sayce, and *Paranaspides lacustris* Smith, also the parasitic crustacean *Cyamus scammoni* Dall, illustrations of all of which are given. After the extraordinary interest of the finely developed specimens in the plates representing *Neolenus*, attention will be drawn by those of *Isotelus*, *Triarthrus becki* Green, and other Ordovician trilobites, together with

[1] *The trilobite: New and old evidence relating to its organization.* Bull. Mus. Comp. Zool. 8: 191–224, pls. I–VI. 1881.

[2] Proc. Biol. Soc. Washington 20: 94. 1894; Smiths. Misc. Coll. 57: 164–208, pl. 24, figs. 1, 1a. 1912; op. cit. pl. 6, figs. 1, 2. 1911; op. cit. pl. 24, figs. 1, 1a; pl. 45, figs. 1, 2, 3, 4. 1912; Text-book Pal. (Zittel), Eastman 2d ed. 1: 701, fig. 1343, p. 716, figs. 1376, 1377. 1913; Smiths. Misc. Coll. 57: 149–153. 1912.

the sections of Cambrian and Ordovician trilobites, and finally the author's conclusions as expressed by several diagrammatic restorations, also sketches of thoracic limbs of trilobites and recent crustaceans, crustacean limbs, and six plates of tracks and trails of trilobites, each adding evidence to the author's deductions as to the appendages.

Some conclusions drawn are that the trilobite's appendages show it to have been a marine crustacean far more highly developed than would have seemed possible in a period so infinitely remote. The following are some of the conclusions:

In its younger stages of growth a free moving and swimming animal, it later became a half-burrowing, crawling, and sometimes swimming animal and moving at times with a flow of the tides and prevailing currents.

Eggs have been found both within and free from the body. It was at home on many kinds of sea-bottom and was able to accommodate itself to muddy as well as to clear water.

It was intensely gregarious in some localities and widely scattered in others, depending upon local conditions, and habits of the various species.

Trilobites had an ample system of respiration by setiferous exopodites, epipodites, and exites attached to the cephalic, thoracic, and abdominal limbs, (as shown in restorations of the limbs on plates 34 and 35.)

The structure of the gnathobases of the cephalic limbs indicates soft food such as worms, minute animal life, and decomposed algae. The trilobite persisted from far back in pre-Cambrian time to the close of Carboniferous time. . . . and left its remains more or less abundantly through about 75,000 feet of stratified rocks.

The paper is profusely illustrated and carefully indexed

G. R. BRIGHAM.

NAVIGATION.—*The search for instrumental means to enable navigators to observe the altitude of a celestial body when the horizon is not visible.* G. W. LITTLEHALES. Proc. U. S. Naval Inst. 44: No. 8. August, 1918.

The necessity of seeing the horizon, in order to find the latitude and longitude of a ship at sea, has generally precluded the taking of observations of altitude at night when the number of celestial bodies shining in the firmament is the greatest and would present the most numerous opportunities for determining geographical position if the altitude could be measured without reference to the sea horizon. And even during the daytime navigators are often sensible of this inconvenience on account of the obscuration of the horizon by haze or fog while the luminary continues to be visible.

While adverting to the instances in which the spirit-level or liquid column has been adapted to instruments similar to the sextant, the main object has been to give an account of the evolution of a dynamical artificial horizon for use at sea and, especially, of the gyroscopic horizon designed as an attachment to the frame of the sextant of reflection.

G. W. L.

NAVIGATION.—*Altitude, azimuth, hour angle.* G. W. LITTLEHALES. Proc. U. S. Naval Inst. 43: No. 11. November, 1917.

This paper presents a chart or diagram for finding, by a simple graphic method, hour angle or azimuth at sea. This chart is based upon the function of the angle called the haversine (half versed sine), not generally employed outside nautical circles, and the formula used as a basis is:

$$\text{hav}(a) = \text{hav}(b \sim c) + \text{hav}(b + c) - \text{hav}(b \backsim c)\ \text{hav}\ A$$

If the sides, b, c, be regarded as constants, a, A, being variables, this expression takes the form,

$$y = mx + C$$

which is the equation of a straight line.

Based on this, a square chart is given, with sides graduated according to values of a series of natural haversines, by means of which hour angle and azimuth may be found, when the altitude and declination of the body and the latitude of the place are given. By drawing a straight line upon such a chart through two points easily determined, a connection is established between hour angle and zenith distance on the one hand, and between azimuth and polar distance on the other. Hence, with either element of each of these two pairs given, the value of the other may be taken from the chart. The chart itself is 2 feet square and finely graduated so that it may be read with a great degree of accuracy.

The diagram is practical for finding azimuth in sea navigation, and it is possible that in the future it may be adapted so as to be used generally for hour angle purposes as well, especially when the navigation of the air becomes a matter of daily experience. J. F. MEYER.

NAVIGATION.—*The chart as a means of finding geographical position by observations of celestial bodies in aerial and marine navigation.* G. W. LITTLEHALES. Proc. U. S. Naval Inst. 44: No. 3. March, 1918.

Building upon the principle that at any instant of time there is a series of positions on the earth at which a celestial body appears at the same given altitude and that these positions lie in the circumference of a circle marked out by a radius arm whose pivot is that geographical position which has the body in its zenith and whose length is the same arc-measure as the zenith distance or the complement of the altitude the method proceeds to recognize that the difference of the simultaneous altitudes of the same celestial body at two geographical positions is the shortest great circle arc-distance between the circles of equal altitude passing through the two places. By supplying the altitudes and azimuths of the celestial bodies as they would appear at stated intervals of time in a chosen geographical position within the limits of the chart, an observer, in a position as yet unknown, having measured altitude of a celestial body, may at once lay down the locus of his position by comparing the altitude so measured with the tabulated altitude of that body and laying off the difference between the measured and tabulated altitude as an intercept from the chosen geographical position in the direction of the azimuth of the celestial body and toward or away from the bearing of the body according as the measured altitude was higher or lower than the tabulated altitude.

In the illustrative specimen, consisting of a map of the United States, a large compass diagram has been centered at the middle position in latitude 39° and longitude 97°, since the attending tabulation is with reference to this point; and since all altitude-differences are laid off from there, circumferences of equal distances from this point have also been delineated, in order that, with a given altitude-difference, the observer may at once proceed to find the point through which his locus is to be drawn at right angles to the intercept of altitude-difference by passing out by the amount of the altitude-difference to the proper drawn or intermediate circumference along the compass-radial indicated by the azimuth ascertained from the bordering tabulation. G. W. L.

PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

WASHINGTON ACADEMY OF SCIENCES

The Board of Managers met on March 24, 1919. The report of the special committee on distribution of the *Proceedings* was adopted, providing for the supplying of certain libraries from the excess stock on hand.

The following persons have become members of the ACADEMY since the last report in the JOURNAL:

Mr. D. DALE CONDIT, U. S. Geological Survey, Washington, D. C.

Professor ERNEST FOX NICHOLS, Yale University, New Haven, Connecticut; and 2022 Columbia Road, Washington, D. C.

Professor ELMER OTTIS WOOTON, Bureau of Plant Industry, U. S. Department of Agriculture, Washington, D. C.

ROBERT B. SOSMAN, *Corresponding Secretary.*

BIOLOGICAL SOCIETY OF WASHINGTON

The 593d regular meeting of the Society was held in the Assembly Hall of the Cosmos Club, Saturday, March 8, 1919; called to order at 8.00 p.m. by Vice-President HOLLISTER; 60 persons present.

Three informal communications were presented:

P. BARTSCH: Remarks on a purple finch which had visited the grounds about his dwelling in the city for three successive seasons. This individual bird had peculiar manners which distinguished it from the several other birds with which it was associated. He had seen it pass from immature to adult plumage.

L. O. HOWARD: Remarks on the spread of the European corn-borer in Massachusetts and New York.

N. HOLLISTER: Remarks on the ovipositing of an Indian python in the National Zoological Park. It is at present brooding on twelve eggs.

The regular program was a symposium: *What kind of characters distinguish a species from a subdivision of a species.*

The discussion was opened by Prof. A. S. Hitchcock, who explained that, as chairman of the committee on communications, he had arranged to have the subject discussed by the exponents of a few of the larger

groups of organisms. It had been impracticable to include a discussion of the very interesting categories, known as physiological species or races, such as the parasitic fungi, among which are races that appear identical morphologically but which are confined to certain host plants, each to each, or such as the bacteria, many forms of which appear identical morphologically but which cause distinct physiological effects, either chemically on artificial substrata, or biologically in producing diverse diseases of plants and animals. Mr. Hitchcock further stated that much of our difficulty in determining whether a given form represents a species or a subdivision of a species results from our ignorance. We do not have sufficient facts. If we are compelled to draw conclusions from a single specimen in a herbarium or even from several specimens we can give only an opinion as to the relation of this form to others, an opinion strengthened, it is true, by training and experience, but at best only an opinion. If we have all the facts, or enough so that lacking data may be safely ignored, our problem is to interpret results and define relations.

Mr. N. HOLLISTER said: Nearly all systematic mammalogists now distinguish subspecies from species by the test of intergradation: some workers insist upon an actual blending of characters over continuous range between typical subspecies, while others admit what is known as "intergradation of characters," even between insular forms, to be sufficient reason for the use of the trinomial. Old conceptions of what is a species are now lightly considered, and authors are frequently inconsistent in their treatment of forms. A good definition of a species was given a few years ago by one writer who stated that "a species is a thing described as such." The same kinds of characters, or precisely the same character, may serve in different instances for distinguishing subspecies, species, or even genera. The difference in the number of the enamel folds in the last upper molars of the capybaras of Surinam and Paraguay was cited as a case where a character sometimes of generic weight serves only to separate subspecies. Specimens showing the process of the loss of one fold are found in Brazil midway between the two typical races. It is a common experience for the monographer working with material assembled from many collections to reduce numerous described species to the rank of subspecies; the forms so treated still retain exactly the same characters that served them as full species.

Dr. H. C. OBERHOLSER spoke on the question from the standpoint of an ornithologist. He said: Most ornithologists at the present time regard the distinction between a species and a subspecies as one of the presence or absence of intergradation. In other words, a subspecies is an imperfectly segregated species—a form occupying a separate geographic area and intergrading with some other form. This intergradation may take place: (1) by gradual change over contiguous geographic areas; (2) by an abrupt change in an intermediate area; (3) by individual variation, whether or not the ranges of the two forms adjoin. The amount of difference does not constitute the distinction

between a species and a subspecies, because even very closely allied forms are species, if their characters are trenchant and the birds do not freely interbreed; while, on the other hand, however great the differences may be between two forms, they are to be regarded as subspecies if intergradation exists.

Dr. N. C. KENDALL'S remarks were published in a recent number of this JOURNAL (9: 187. 1919).

Dr. P. BARTSCH speaking on the question with respect to mollusks said: There are no hard and fast lines that can be invariably employed in deciding to which nomenclatorial category a certain form should be assigned. He thought that in the present imperfect state of our knowledge, most designations were largely a matter of judgment and expediency. Systematists at present unfortunately recognize only two categories, species and subspecies, by means of which they attempt to designate all the products of Nature's laboratories. This makes all sorts of compromises necessary in order to squeeze a given form into the one or the other of the two. It is his firm belief that when the work of experimental biologists and breeders, which is heaping up a pile of data, will have advanced a little further, we shall be furnished with a mass of information which will demand recognit on of a larger series of categories designed to express the true inwardness of phylogenetic relationship a little more definitely than it is expressed by our present system of nomenclature.

In many instances it is not difficult to decide the status of a form. The old definition that "A species embraces an aggregation of individuals which may differ in age, sexual, seasonal or individual characteristics" is easily enough applied in many instances; likewise can be applied the definition for the subspecies, which simply makes it necessary to have connecting elements between two such groups, but what shall be done with a case like the following?

"In the Philippine Islands we have, as far as known, only a single species of *Vivipara* in a given region. In Lake Lanao, on the other hand, we have apparently about forty. At all events there seem to be that many constant forms, for the young which I have extracted from probably more than a thousand individuals have always agreed with the parents in sculptural characters. The range of form modifications in these Lake Lanao viviparas can best be seen by consulting my papers on the group.[1] Another paper on this topic is almost completed. This is based on an examination of about 3,000 specimens. What designation shall be given to forms like these? These are probably the result of cross breeding between two distinctly related stalks of the genus. At least my Cerion breeding experiments would indicate this.

[1] *The Philippine pond snails of the genus Vivipara.* Proc. U. S. Nat. Mus. 32: 135–150. pls. 10 and 11. 1907; *Notes on the Philippine pond snails of the genus Vivipara, with descriptions of new species.* Proc. U. S. Nat. Mus. 37: 365–367. 1909.

Sometimes I have deliberately used a trinomial when the data at hand really indicated a binomial. Let me explain by an example. The genus *Leptopoma* has probably twenty phylogenetic stalks or superspecies in the Philippine Archipelago. Some of these groups have in the past been considered a single widely distributed very variable species. The abundant material which is rapidly accumulating in the U. S. National Museum proves conclusively that every island has its distinct form, and the larger islands, where faunal barriers exist, may have two or more. In some cases, intergradations exist, while in others they do not. Now the rule would say, designate the distinct forms as species and those with intergrades as subspecies, but how much more rational to consider the entire complex under one specific, name and the various races under a trinomial—at least for the present until material from the entire range showing all possible phases of these groups will have been examined, for by so doing one has the advantage of knowing at once that the organism in question is the *Leptopoma nitidum* representative of Luzon, or a member of the *Leptopoma goniostoma* group."

Mr. A. N. CAUDELL as an entomologist said: In his work on the Orthoptera he recognized two grades below the species, that is the geographical race, or subspecies, and the variety. He gave the following definitions:

Species. A group of individuals separable from allied groups by appreciable external morphological characters of a sufficiently stabilized nature to prohibit a general mergence through variation, based on a biological foundation sufficiently firm to assure breeding true to nature, and the production of fertile progeny.

Geographical race. An assemblage of individuals of a species distinguishable from each other, and from the dominant form, by appreciable external morphological characters and occupying different, but adjacent, geographical regions, at the junction of which complete mergence through variation occurs. In other words, races are incipient species originating through variation caused by diverse environmental conditions due to geographical distribution.

Variety. Individuals of a species or of a race varying more or less from the typical in external morphological or colorational characters, not with relation to geographical distribution and subject to complete integration through variation.

Each of these groups was briefly discussed and emphasis was given the fact of this being the present personal opinion of the speaker and not intended in any way to represent the views of entomologists in general. It was admitted that for use in a broader way, especially in higher zoological groups, the definition of species should be broadened to include physiological characters, and also, probably, biological features.

Dr. S. F. BLAKE discussed the question from the botanical aspect: A subspecies in botany, as in zoology, is ordinarily distinguished from a species by the fact that it intergrades with a related form or forms,

while a species does not. Two kinds of intergradation must be distinguished, that due to fluctuating variation, which indicates subspecific rank, and that due to hybridism, which may occur between species. As most systematic work is done with herbarium specimens, it is not possible to distinguish these by breeding tests, and their discrimination is a matter of judgment and experience. Furthermore, the absence of intergradation is not in itself a criterion of specific rank. Many unit-character forms, very distinct in appearance, such as albinos or forms with peculiar leaves, will not be found to intergrade, and they even have rather distinct geographical ranges. In such cases the rank to be given the form in question depends on the extent of the botanist's field experience. In general, forms distinguished by several constant characters are species; forms distinguished by only one or by inconstant characters, subspecies; but there is no absolute test which can be applied, and in doubtful cases the decision depends on the experience and point of view of the botanist.

Each of the above speakers was limited to ten minutes for the presentation of his remarks. After the formal remarks a general discussion ensued in which Messrs. A. S. HITCHCOCK, A. N. CAUDELL, P. BARTSCH, N. HOLLISTER, S. A. ROHWER, L. O. HOWARD, V. BAILEY, and M. W. LYON, JR., took part.

M. W. LYON, JR., *Recording Secretary.*

SCIENTIFIC NOTES AND NEWS

An executive order by the President, dated February 26, 1919, transfers twenty-three former officers of the U. S. Coast and Geodetic Survey from the War Department back to the jurisdiction of the Survey; and forty-six officers, similarly, from the Navy Department to the Survey. Five Survey vessels are also returned. The transfers are to become effective before April 1, 1919.

The Bureau of Mines has sent a special mission to Europe to collect information on the methods discussed and those adopted in the rebuilding of the mining and metallurgical plants and industries in the devastated areas. The members of the mission are: F. G. COTTRELL, chief metallurgist; G. S. RICE, chief mining engineer; W. PERDUE, petroleum technologist; and F. K. PROBERT of the University of California, consulting mining engineer. The mission will have headquarters in London.

Messrs. HOYT S. GALE and J. B. UMPLEBY, of the U. S. Geological Survey, have gone to France to investigate certain questions of mineral resources, particularly potash salts, involved in the peace negotiations.

Dr. OLAF ANDERSEN, of the Mineralogical Institute, Kristiania, Norway, visited Washington in March.

Lieut. Col. W. D. BANCROFT, of the Chemical Warfare Service, has been elected Chairman of the Division of Chemistry and Chemical Technology of the National Research Council.

Dr. W. N. BERG, formerly captain in the Sanitary Corps, and stationed at Camp Lee, received his honorable discharge from the Army in March and has returned to the Bureau of Animal Industry.

Major CHARLES HARROD BOYD, for forty years an officer of the Coast and Geodetic Survey, died on February 9, 1919, at his home in Portland, Maine, in his eighty-sixth year. He entered the Survey in 1855, served with the Port Royal expedition in 1861, and served under Gen. Barnard on the fortifications near Washington later in the war, retiring from the Survey in 1894.

Dr. H. L. CURTIS, of the Bureau of Standards, has gone for a three months visit to European laboratories to obtain data on the progress of certain war problems.

Dr. ALFRED C. HAWKINS, recently appointed crystallographer in the laboratories of E. I. du Pont de Nemours and Company, is spending a few weeks in studying recent advances in this subject at the Bureau of Chemistry and other Washington laboratories.

Capt. P. E. LANDOLT of the Nitrate Division, Army Ordnance, has resigned from the service and has returned to his work as chemical engineer with the Research Corporation at New York City.

Dr. A. O. LEUSCHNER, who has been with the National Research Council since November, 1918, returned to the University of California in the latter part of March.

Mr. JAMES W. MCGUIRE, of the Coast and Geodetic Survey, has been appointed a member of the U. S. Geographic Board.

Lieut. Col. WILLIAM MCPHERSON, Chemical Warfare Service, Professor of Chemistry at the Ohio State University, Columbus, Ohio, who was stationed in Washington in the early part of the war and was later sent to France, received his honorable discharge from the Army in March, and has returned to the University.

Dr. W. B. MELDRUM, professor of chemistry at Haverford College, and until lately a member of the Chemical Warfare Service and of the price section of the War Trade Board, has received a temporary appointment as assistant physical chemist at the Geophysical Laboratory, Carnegie Institution of Washington.

Professor SEM SAELAND, Professor of Physics and Rektor of the Technological Institute of Norway, at Trondhjem, Norway, visited Washington in March.

Dr. H. C. TAYLOR, head of the department of agricultural economics in the College of Agriculture, University of Wisconsin, has been appointed Chief of the Office of Farm Management, Department of Agriculture.

Col. W. H. WILMER, Medical Corps, U. S. A., returned to Washington on March 22. He expects to continue in the Army for a period to write the history of the laboratory work of the Air Service in France.

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